EXPLOSIVE PRESSURE WAVE CONCENTRATOR

BACKGROUND OF THE INVENTION

This invention is concerned generally with a customized low energy method of breaking rock in a controlled manner.

As used herein the word "rock" includes rock, ore, coal, concrete and any similar hard mass, whether above ground or underground, which is difficult to break or fracture. It is to be understood that "rock" is to be interpreted broadly.

A number of techniques have been developed for the breaking of rock using non-explosive means. These include a carbon dioxide gas pressurisation method (referred to as the Cardox method), the use of gas injectors (the Sunburst technique), hydrofracturing and various methods by which cartridges containing energetic substances pressurise the walls or base of a sealed drill hole to produce a penetrating cone fracture (known as PCF).

These techniques may be an order of magnitude more efficient than conventional blasting in that they require approximately 1/10 of the energy to break a given amount of rock compared to conventional blasting using high explosives. The lower energy reduces the resulting quantity of fly rock and air blast and to an extent allows the rockbreaking operation to proceed on a continuous basis as opposed to the batch-type situation which prevails with conventional blasting.

Most non-explosive rockbreaking techniques rely on the generation of high gas pressures to initiate a tensile fracture at the bottom or sides of a relatively short drill hole.

Efficient confinement of the gas produced in the hole is a prerequisite for ensuring that the available energy is effectively used to break the rock. Problems with confining the gas in the hole which arise with current methods of non-explosive breaking are often due to the jointed or fractured nature of the rock in its natural state.

A jointed rock with open joints that traverse the drill hole in the rock will tend to terminate any cracks that are propagated by high-pressure gas toward the open joint by dissipating the gas pressure in the cracks at the intersection of the open joint. The result is that in a hole which is relatively long, where open joints are present, there is a difficulty in fragmenting the rock effectively over the length of the hole.

Attempts to deck the hole with separate charges of energetic substance separated by plugs of stemming run into the problem that each pressurised portion of the hole must develop a breaking point in the rock in order to propagate cracks. Due to the relatively low pressure

environment which prevails in the hole when use is made of propellants, compared to the high pressure environments which exist with explosives, it is not always possible for the pressurised sections of the hole to create new cracks in the rock with the result that the pressure in the hole tends to dislodge its confining stemming material to form a "blow-out' of the stemming through the collar of the hole.

Thus, if the hole can be pressurised in separate sections and each of the pressurised sections can act independently to break its respective section of the hole, the problem of premature termination of crack propagation and the problem of blow-outs can be overcome or alleviated.

Low energy rockbreaking methods, such as those using propellants, generally use high gas pressures to propagate fractures originating from microfractures and points of weakness in the rock such as joints, fissures and faults. Depending on rock conditions and mining requirements such as breaking rock to a particular size, it may be desirable to induce a region of high stress concentration at any chosen location, at the bottom or otherwise, in the drill hole, to initiate new fractures in the rock. An object of the present invention is to achieve such a result.

It is also desirable for a variety of reasons to be able to initiate fracture of the rock at a predetermined location which is not, necessarily, at the bottom of the drill hole.

When the propellant is initiated a pressure wave is generated which propagates away from the point of initiation. It is desirable to be able to reinforce the pressure wave or increase the energy density which is obtainable from the ignited propellant so that localised high pressure regions can be generated to initiate rock fracture at predetermined points.

SUMMARY OF INVENTION

According to the invention a method of breaking rock includes the steps of:

(a) loading at least a first cartridge into a hole in a rock face;
(b) confining the cartridge in the hole;
(c) initiating a propellant in the cartridge thereby to cause the release of pressurised material,
(d) supporting a base of the cartridge to prevent the base from fracturing under the effect of the pressurised material, and
(e) directing the pressurised material at least to a periphery of the base to initiate breakage of rock adjacent the periphery.

In one form of the invention the cartridge is supported at a bottom of the hole.

In an alternative embodiment the cartridge is supported inside the hole at a location which is spaced from the bottom of the hole. The cartridge may be supported, for example, on stemming. With this form of the invention the base of the cartridge is thus separated from the bottom of the hole.

A plurality of cartridges may be used inside the hole. Thus a first cartridge may be positioned at a first location at or near a bottom of the hole and a second cartridge may be positioned at a second location in the hole which is spaced from the first location. Third or even fourth cartridges may be employed according to requirement.

Stemming may be positioned inside the hole between successive cartridges.

According to a different aspect of the invention there is provided a method of breaking rock which includes the steps of:

(a) supporting a plurality of cartridges at respective locations in a hole in a rock face, the respective locations being spaced from each other in an axial direction of the hole,

(b) igniting propellant in the respective cartridges thereby to cause the release of pressurised material inside each cartridge, and

(c) at each location directing force which is generated by the respective pressurised material onto a respective surface of a wall of the hole at or near a base of the respective cartridge.

The invention may include the step of deforming the pressure wave to create at least one region inside the hole which has an increased stress concentration.

At the region the energy density of the wave may be greater than elsewhere in the hole. This creates a stress point in the rock at or adjacent the region.

The pressure wave may be deformed in any appropriate way, using any suitable technique. Without being limiting the pressure wave may be deformed by at least one of the following: by shaping the cartridge at one or more regions to induce pressure wave deformation; by inserting or forming one or more wave deforming members on an inner or outer side of the cartridge; by locating one or more wave deforming members inside the cartridge.

In one form of the invention the pressure wave is deformed by suitably shaping a base or a side wall of the cartridge.

In one embodiment the method includes the step detonating a first high-explosive inside the hole to generate a localised explosive shock wave in the rock.

Step (c) may be carried out, according to requirement, substantially simultaneously with or slightly before or slight after, the last mentioned step.

In the last mentioned step more than one high-explosive may be detonated. These high-explosives may be detonated substantially simultaneously or a second high-explosive may be detonated a predetermined time period after detonation of the first high explosive.

The method may include the step of deforming the pressure wave which is produced by the propellant. The pressure wave may be deformed in a region which is close to or substantially coincident with the region in which the high explosive is detonated in step (c).

In a variation the method includes the step of generating a high pressure jet of a second material which has a density which is greater than the density of the pressurised material.

Stemming material of any appropriate kind may be placed in the hole over the cartridge in a manner which is known in the art.

The cartridge may be used to confine the pressurised materials in the cartridge whereby the cartridge is expanded into sealing engagement with a wall of the hole surrounding the cartridge so that, initially, the cartridge reinforces the wall of the hole.

To allow the aforementioned sealing engagement of the cartridge with the wall of the hole the cartridge may be made from a malleable material. "Malleable" in this sense includes a material which is capable of plastic deformation, without fracture, at least to the point at which the cartridge is in close contact with the surrounding wall of the hole.

The cartridge, when it fractures, allows the high pressure materials to initiate rock breakage.

The high pressure jet of the second material may be generated at one or more predetermined positions in the cartridge.

The high pressure jet of the second material may be generated by the action of the pressurised material, released in step (c), on at least one member which includes the second material.

Alternatively or additionally to the aforegoing the high pressure jet of the second material may be generated by the action of an explosive on at least one member which includes the second material.

The explosive may be detonated by the action of the pressurised material or it may be directly detonated by suitable control means substantially at the same time as the propellant is initiated or slightly before or slightly after the time at which the propellant is initiated.

The propellant may be initiated at a first predetermined time, at least at a first zone, and the method may include the step at a second predetermined time of carrying out at least one of:

(i) detonating an explosive in the hole, and

(ii) initiating the propellant at least at a second zone in the hole.

The first and second predetermined times can, in essence, be coincident. However a predetermined interval may exist between the first and second predetermined times.

According to requirement the first predetermined time may be before the second predetermined time, or vice versa.

The explosive in the hole may be separate from the cartridge and may be physically displaced from the cartridge. Alternatively the explosive may be inside the cartridge or on an outer side of the cartridge.

Where a time interval exists between the first and second predetermined times the duration of the time interval may be controlled by using electronic techniques.

The propellant and the explosive may be initiated and detonated, respectively, by means of respective control signals which are transmitted from a control unit or units via control lines or by using wireless techniques.

The method may include the steps of creating at least two pressure waves, resulting from initiation of the propellant or propellants, and allowing the pressure waves to interfere with each other at a predetermined region.

In one form of the invention each pressure wave is generated by initiating a respective propellant.

In a different form of the invention the pressure waves are generated by initiating the propellant at two respective points which are spaced from each other.

The pressure waves may be generated inside a single enclosure. In a different form of the invention each pressure wave is generated inside a respective enclosure.

According to a different aspect of the invention there is provided a method of breaking rock which includes the steps of:

(a) loading a cartridge into a hole in a rock face;

(b) initiating a propellant in the cartridge, at least at first and second points which are spaced from each other in the cartridge, thereby to generate at least two wave fronts

which are caused to interact with each other, each wave front causing the release of pressurised material; and

(c) confining the pressurised material in the cartridge.

The cartridge may be elongate and the first and second points may be located respectively at opposed ends of the cartridge.

The initiation of the propellant at the first and second points may occur substantially simultaneously or initiation at one point may take place at a predetermined time interval after initiation at the other point.

According to another form of the invention there is provided a method of breaking rock which includes the steps of loading first and second cartridges into a hole in a rock face and initiating respective propellants in the cartridges at respective first and second points thereby to cause the generation of pressure waves which are allowed to interact with each other at a location which is between the first and second points.

The invention also provides apparatus for breaking rock which includes a first cartridge with a base and a side wall which form an enclosure, and a propellant inside the enclosure, and wherein a discontinuous relatively weaker region of the container is formed at a junction between the wall and the base.

The cartridge may be generally cylindrical in shape and the base may be substantially at right angles to a longitudinal axis of the cartridge.

The base may be substantially more robust than the wall of the container and to achieve this the base may be made from a stronger or thicker material than the wall.

In one embodiment of the invention the base is shaped to direct a wave of pressurised material, produced by the ignited propellant, towards a periphery of the base. This may be achieved in any appropriate way and, for example, the base, on an internal surface, may be substantially conical in shape.

The apparatus may include at least one pressure wave deforming member which is exposed to a pressure wave generated by initiating the propellant.

The cartridge may include a device for initiating the propellant.

The pressure wave deforming member may be selected from the following: at least one formation on or near the base; at least one formation on an inner or outer surface of the side wall; at least one suitably shaped member inside the cartridge, or outside the cartridge; at

least one suitably shaped member inside the propellant positioned at a desired distance relatively to the base.

The apparatus may include at least one high-explosive charge on or inside the cartridge.

The apparatus may include at least one pressure wave deforming member which is positioned inside or outside the cartridge and at a region which is adjacent the location at which the high-explosive charge is located.

The cartridge is preferably made from a plastically deformable material. Thus the cartridge may be made from a material which is capable of plastic deformation, without rupturing, by at least a predetermined extent eg. by at least 10%.

In one embodiment the apparatus includes at least one member, which is made from a material which has a density greater than the density of the propellant, on or inside the cartridge.

The density of the member should, within reason, be as high as possible. For example iron has a density of the order of 7,8 and other metals or substances have densities in excess of this. Lead for example has a density of approximately 11,3. Uranium has a density of the order of 19. These substances are given merely by way of example as being suitable for use in the apparatus of the invention. In the last mentioned case it is preferable to make use of uranium in its depleted form to minimise radioactivity consequences.

The member may be positioned at a predetermined point inside the cartridge.

The member may be turned into a high pressure jet by the action of the propellant when it is ignited. Alternatively or additionally an explosive which acts directly on the member may be used to generate a high pressure jet of the material.

The means which is used for igniting the blasting agent may be used for detonating the explosive. Alternatively a separate initiator is used for detonating the explosive independently of the means which is used for igniting the blasting agent.

The apparatus may include an explosive, and a control unit which initiates the propellant at a first predetermined time and which detonates the explosive at a second predetermined time.

The first and second predetermined times may be coincident or a predetermined time interval may exist between the first and second predetermined times.

The control unit may be an integral mechanism or may include a first mechanism which is used for initiating the propellant and a second mechanism which is used for detonating the explosive.

The explosive may be separate, ie. physically displaced, from the cartridge, positioned on an outer surface of the cartridge, or located inside the cartridge.

The control unit may be used for generating control signals which are transmitted to the propellant and to the explosive respectively, for initiation and detonation thereof. The control signals may be transmitted using communication links of any appropriate kind eg. physical conductors or optic links, or by making use of wireless techniques or the like.

The apparatus may include at least first and second initiators for igniting the propellant at respective first and second points which are spaced from each other inside the cartridge.

In another form of the invention there is provided apparatus for breaking rock which includes first and second cartridges, each cartridge forming a respective enclosure for a respective propellant, each cartridge including a respective initiator for igniting the propellant in the respective enclosure, and wherein the cartridges are positioned in an assembly with the initiators at opposed remote points in the assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further described by way of examples with reference to the accompanying drawings in which:

Figure 1 illustrates from the side and in cross section apparatus according to one form of the invention;

Figures 2 to 8 respectively illustrate from the side and in cross section different forms of apparatus for breaking rock according to the invention;

Figures 9, 10 and 11 respectively illustrate different forms of apparatus for breaking rock according to the invention;

Figure 12 is a side view in cross section of apparatus for breaking rock according to another form of the invention;

Figure 13 is a side view in cross section of apparatus for breaking rock according to a further form of the invention;

Figure 14 is a side view in cross section of apparatus for breaking rock according to a variation of the invention;

Figure 15 schematically illustrates a control circuit which is used in the method of the invention;

Figure 16 illustrates an alternative control circuit for use in the method of the invention; and

Figures 17 to 19 respectively illustrate apparatus for breaking rock in accordance with different embodiments of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 of the accompanying drawings illustrates a hole 10 which is formed in rock 12 by drilling from a rock face 14 using conventional drilling machines and techniques which are not further described herein.

The hole 10 has a length 16 and a diameter 18. The hole has a bottom 20 which, ideally, is substantially at right-angles to side walls 22 of the hole. It is to be noted however that this ideal is rarely reached in practice for due to wear of the bit which is used for drilling the hole 10 or poor operator technique the "corners" 26 between the bottom 20 and the wall 22 are often concave in shape with the result that the bottom 20 is normally at least slightly rounded.

A cartridge 30 is loaded into the hole so that its base 32 is in contact with the bottom 20 of the hole. The cartridge is made from any appropriate material, such as, for example, a high density plastics material. The cartridge includes a side wall 34 which extends upwardly from the base 32 and which is generally of circular cylindrical shape. At an upper end 36 the cartridge 30 is domed in shape.

The base 32 has a thickness 38 which is significantly greater than the thickness 40 of the wall 34. The base 38 is therefore substantially more robust than the wall 40. The cartridge is filled with a propellant 42 which can be ignited by means of an initiator 44, of known construction, which is located within the cartridge . Control wires 46 lead from the initiator 44 to a control unit which is used for controlling the breaking operation. The control unit is of a type which is known in the art and consequently is not further described herein.

As used herein "propellant" is to be interpreted broadly to include a propellant, blasting agent, explosive, gas-evolving substance, or similar means which, once initiated, generates high pressure material typically at least partly in gaseous form. Propellants of this nature are known in the art. Propellant and blasting agent are used interchangeably.

Stemming 50 is positioned inside the hole 10 over the cartridge 30 to a desired extent. Thereafter a cartridge 52 is loaded into the hole, resting on the underlying stemming. The amount of stemming 50 placed in the hole is such that the cartridge 52 is consequently supported inside the hole at a desired spacing from the lower cartridge 30.

It is apparent that further cartridges can be supported inside the hole, according to the length of the hole and blasting requirements. The present invention is however described with reference to the use of two cartridges inside the hole but this is a non-limiting example.

The cartridge 52 is in many respects similar to the cartridge 30 and components which are the same as components in the cartridge 30 bear identical reference numerals and are not further described.

It is to be noted however that the base of the cartridge 52, designated 32A, is substantially conical in cross section with an apex 54 of the cone extending into the interior of the cartridge at a central location thereof.

Stemming 56 is placed over the cartridge 52 and tamped in position.

The propellants 42 in the various cartridges are ignited substantially simultaneously by means of control signals applied through the wires 46 to the respective initiators 44. Ignition of the propellants causes the release of high pressure jet material, substantially in gaseous form, in each of the cartridges.

In respect of the cartridge 30 the base 32 is forced downwardly by the high pressure jet material expanding inside the cartridge interior and is driven into close contact with the bottom 20 of the hole. Due to the robust nature of the base gas inside the cartridge is prevented from venting directly onto the bottom 20. The gas is instead directed towards the right angled junction 60 between the walls 34 and the base 32 which, at least due to its shape, is discontinuous and therefore constitutes a line of weakness. The junction 60 could, if desired, be deliberately weakened by reducing the quantity of material which is used at the junction.

The base 32 thus provides a solid surface which, at least initially, is gas impermeable and the high pressure gas thus fractures the junction 60 and is thereby directed into that portion of the wall 26 ("the corners") which surrounds the junction. Fracture of the wall is thereby induced or initiated at this region.

In respect of the cartridge 52 the base 32A is, as before, significantly robust and is also forced by the high pressure jet material expanding inside the confinement structure constituted by the cartridge onto the underlying stemming 50. The stemming 50 in conjunction with the base 32A effectively defines a "false" bottom of the hole, insofar as the cartridge 52 is concerned. The high pressure material inside this cartridge is then directed by the conical upper surface of the base 32A towards the peripheral region 26A of the base which, as before, is discontinuous or weakened so that pressure release takes place, at least

initially, at this region. The gas which is released at the side wall, in the region of the periphery of the base, fractures the rock at this region.

The invention thus provides a technique whereby the wall of a relatively elongate hole, in the rock face, can be fractured at two or more points which are spaced from one another by inducing localised stresses at these points. At locations other than the bottom of the hole the localised stresses result from creating a "false" hole bottom by using a robust base of the cartridge which is supported by means of the underlying stemming and which is shaped to direct the pressurised material, released by the ignited propellant, towards the surrounding wall of the hole to cause its fracture.

A principal benefit of the method of the invention is that a relatively large amount of rock over an extended hole distance can be released in a manner which makes efficient use of propellant and which allows cycle times for blasting and clearing to be contained.

In the following description reference numerals which are the same as those used in connection with Figure 1 are used, where applicable, to indicate like components.

Figure 2 illustrates a hole 10 with a length L which is of the order of at least four times the diameter D of the hole.

A cartridge 30A is loaded into the hole. The cartridge has a base 32 and a cylindrical side wall 34 which extends upwardly from the base and which, at an end which is remote from the base, has a rounded shape.

The base and the wall 34 form an enclosure for a propellant 42 of any appropriate composition. The propellant is compressed into the cartridge under factory conditions using techniques which are known in the art. An initiator 44 is loaded into the cartridge. The initiator is located at the rounded upper end but this is by no means limiting and the initiator can be loaded into the cartridge at any appropriate point.

Control wires 46 lead from the initiator to a unit, not shown, which is used in a known manner for initiating the blasting process.

Stemming 50 is placed into the hole and is tamped or otherwise secured in position.

The base 32A is formed with a central socket-like region 60 which directly opposes a bottom 20 of the hole. The region 60 is flanked by a sloping or conical-like formation 62 which extends downwardly towards a lower extremity of the wall 34.

Ignition of the propellant 42 by the initiator 44 causes the release of high pressure jet material which is substantially in gaseous form. The cartridge 30A is designed to contain the expanding high pressure jet material and is allowed to deform outwardly, without rupturing, so that the wall of the cartridge is forced into sealing contact with an opposing surface of the wall 22 of the hole. The cartridge does not fracture during this process for it is fabricated from a plastically deformable material.

At an upper end the cartridge is contained by the stemming 50.

The high pressure jet material released by ignition of the propellant gives rise to a pressure wave which propagates in the cartridge downwardly as the propellant ignites. The pressure wave strikes the base 32A and the conical formation 62 directs the pressure wave, which impinges on the formation, radially outwardly towards the periphery of the base. The pressure wave is thus deformed and a high energy density region of the pressure wave is produced at lower peripheral extremities of the base more or less at the junction of the bottom of the hole with the side wall 22. This causes fracturing of adjacent regions of the rock.

It is possible to deform the pressure wave generated by the ignited propellant in a variety of ways. The invention is not restricted in this regard. In Figure 2 a base of the cartridge is shaped to produce the desired way of deformation. As a consequence rock fracture is initiated at the bottom of the hole.

Figure 3 illustrates an alternative technique wherein a cartridge 30B is placed in a hole 10 and covered with stemming 50. There are strong similarities between the arrangement shown in Figure 3 and that shown in Figure 2 and for this reason components which are the same in the two embodiments bear like reference numerals. It is to be noted however that in the Figure 3 embodiment of the invention the base 32 is planar and, to a substantial extent, rests on the bottom 20 of the hole. Thus the base is not used, in itself, to deform the pressure wave inside the cartridge.

Two rings 64 and 66 are positioned inside the cartridge and are secured to the inner surface of the wall 34 by means of a suitable adhesive. This step is taken before the propellant 42 is placed inside the cartridge.

When the propellant is ignited a pressure wave is transmitted through the combusting charge. Discontinuities are created by the rings 64 and 66 which present localised barriers to propagation of the wave. Although the resulting effect on the pressure wave is complex high energy regions of the pressure wave are generated in the vicinity of each ring. It is believed that the deformation of the pressure wave gives rise to interference between two or

more pressure wave fronts and this in turn gives rise to an increase in the energy density. Another factor is that the pressure wave passes through a region of a first set of properties, ie. those of the combusting propellant, into a region with a second set of properties, ie. those arising from the material of each ring. This causes diffraction effects and, again, the pressure wave is deformed. The applicant has established through experimentation that by choosing the size and position of the rings correctly the rock can be caused to fracture at regions other than the bottom of the hole.

In the arrangement shown in Figure 4 a discontinuity is created inside the interior of a cartridge 30C by forming the side wall 34 with an internally extending circumferential channel or recess 68. The channel 68 has an effect similar to that of the ring 64 in that a localised high stress region is produced by deforming the propagating pressure wave which is generated by combustion of the propellant 42.

Figure 5 illustrates a cartridge 30D which has a ring 70 at a desired location on an outer surface of the side wall 34. When the propellant 42 is ignited the wall is forced radially outwardly into close sealing contact with the wall 22 of the hole. The ring 70 is however not compressible to any significant extent and consequently forms an inwardly extending peripheral rib or ridge which acts in a manner which is similar to that of the ring 64 in Figure 3. Once again the pressure wave is deformed and a localised high energy region is produced which gives rise to fracture of the rock at a region which is close to the ring 70.

Figure 6 shows a cartridge 30E with external ribs 72 and 74 respectively which are integrally formed with the side wall at selected locations. The ribs 72 and 74 function in the same way as the ring 70 shown in Figure 5 in that they deform the pressure wave and produce high energy stress regions which promote localised cracking or fracture of the opposing rock surface.

Figures 7 and 8 illustrate that it is possible to deform the pressure wave inside the cartridge by using members which are not at a periphery of the cartridge. In the Figure 7 arrangement a cartridge 30F with a regular side wall 34 and a planar base 32 is positioned in a hole 10. A solid insert 76 is positioned inside the propellant 42. The insert is supported on a stalk 78 which extends upwardly from the base 32. The size of the insert 76 may vary according to the degree of pressure wave deformation which is required. Although the resulting situation is complex and at least to some extent the size and position of the insert may be required to be determined empirically it is possible to produce localised high stress regions in order to promote rock fracture at one or more predetermined locations.

The cartridge 30G shown in Figure 8 is similar to that shown in Figure 7 in that an insert 80 is effectively imbedded in and surrounded by the propellant 42. In this instance however the insert is supported on small arms 82 which extend from an inner surface of the side wall 34.

It is to be noted that the cartridge confines the expanding high pressure jet material which is released by the ignited propellant in such a way that the cartridge is expanded and is thereby forced into contact with the surrounding wall of the rock. As the pressure wave propagates through the cartridge interior the pressure wave deforming member or members, which can take on a variety of forms, produce localised high energy regions which promote rock fracture at predetermined points in the rock mass.

In the arrangement shown in Figure 9 two rings 84 and 86 of high-explosive material are positioned inside a cartridge 30H at desired locations and are secured in position using any appropriate technique. In the illustrated example the ring 86 rests on the base 32 of the cartridge while the ring 84 is adhesively secured to the inner surface of the wall 34. The nature of the high-explosive material may vary according to requirement and for example may comprise CORTEX or P10 (these are registered trade marks) or the like. The high-explosive material may also comprise or include aluminium powder or any other high energy content material.

When the propellant 42 is ignited a pressure wave propagates through the cartridge interior as combustion of the propellant takes place. High pressure material is released by the combusted propellant. The high-explosive rings 84 and 86 are also detonated at precisely controlled times. When the high-explosive ring 84 is detonated an explosive shock wave is generated which reinforces the propellant pressure wave. Another effect which comes into play is that the explosive shock wave can increase the efficiency of combustion of the propellant and in this way enhance the propellant pressure wave. It is believed that the explosive shock wave can act as a booster to the propellant pressure wave and thereby increase the intensity of the shockwave on the rock. In essence therefore respective or separate shock waves and pressure waves are generated by each high-explosive ring and the propellant respectively. Particularly in the regions of the high-explosive rings 84 and 86 high energy stress regions are created in the adjacent rock masses.

The cartridge 30H initially expands plastically confining the high pressure material which is released by the combustion and explosive processes. Substantial force is thereby generated inside the cartridge. As the cartridge fractures the energy released by the explosive rings 84 and 86 combined with the energy contained in the pressure wave from the propellant 42 results in localised fracture of the rock at least initially in the region of the ring 84 and at the bottom of the hole.

In the example of the invention shown in Figure 10 components which are the same as those described in connection with Figure 9 bear like reference numerals and are not further described herein.

In the Figure 10 embodiment an explosive ring 88 is positioned on an external surface of the cartridge 30J. The explosive ring is detonated at a carefully chosen time relatively to the instant at which the propellant 42 is ignited. Once again the pressure wave produce by the propellant is enhanced or boosted by the shock wave generated by the detonation of the explosive 88.

Figure 10 illustrates a further variation in that alternatively or in addition to the ring 88 an explosive charge 90 may be positioned inside the propellant 42. In the first instance the charge 90 acts to deform the pressure wave which is produced by the propellant 42 while a second effect arises, in a manner similar to what has been described, once the explosive 90 is detonated in that a booster shock wave is generated which enhances the effect of the propellant pressure wave.

Figure 11 illustrates an embodiment of the invention in which deformation of the propellant pressure wave is achieved by means of a ring or any other appropriate deforming member 92 which, in this example, is positioned inside the cartridge 30K. An inwardly extending peripheral groove 94 is formed in the side wall 34 of the cartridge and the ring 92 rests on the groove. The groove is externally filled with explosives 96 which is sealed in position by means of a surrounding cover strip 98. When the propellant 42 is ignited the ring 92 acts to deform the resulting pressure wave and this gives rise to a high energy region of the pressure wave in the vicinity of the ring 92. The explosive 96, once detonated, produces an explosive shock wave which enhances the high energy region and this promotes fracture of the rock body in the locality of the ring and the groove 94.

An important aspect of the invention resides in the ability of the cartridge to contain the propellant pressure wave so that premature release of the energy generated by the propellant combustion does not take place. The shock wave which is caused by detonation of the explosive enhances the propellant pressure wave and once the cartridge fractures the rock mass is caused to fracture by the release of high pressure jet material directed at the rock at a controlled region which is determined beforehand.

The explosive charges can be detonated by means of control signals transmitted over wires 46A which are connected directly to the wires 46.

It is possible though to connect the wires 46A to a separate control unit so that, in each case, the respective initiator 44 is initiated at a first time while the respective explosive is detonated at a second time which may be a predetermined period before or after the first time.

In Figure 12 two ring-shaped inserts 100 and 102 are positioned inside a cartridge 30L. The insert 102 rests on the base 32 while the insert 100 is positioned at a predetermined intermediate location. The insert is kept in position by means of a suitable adhesive or alternatively is frictionally engaged with an inner surface of the wall 34. Any other appropriate technique can be used to secure the insert at a desired position inside the cartridge.

The inserts 100 and 102 are made from a material which has a density greater than the density of the propellant 42. Ideally the density of each insert should be as high as possible under the circumstances. The inserts can be made from any appropriate substance which does not have undesirable side effects. For example the inserts can be made from lead or a composition which contains any other heavy metal which is not harmful. It is also possible to make use of depleted uranium, a dense substance which has a reduced radioactivity level.

Ignition of the propellant 42 by the initiator 44 causes the release of high pressure jet material which is substantially in gaseous form and which is directly generated by the combustion of the propellant. The cartridge 30L is designed to contain the expanding high pressure material initially in that it is allowed to deform outwardly without rupturing, so that the wall of the cartridge is forced into close sealing contact with an opposing surface 22 of the wall of the hole. The cartridge does not initially fracture for, as noted, it is fabricated from a plastically deformable material.

The cartridge confines the high pressure gas released by the propellant 42. During this process the inserts 100 and 102, at least to a substantial extent, remain integral.

The pressure wave which is generated by ignition of the propellant 42 advances through the cartridge. The insert 100 deforms the pressure wave and this results in a high energy region being established at the locality of the insert. This, in itself, helps to cause the rock to crack once the cartridge fractures as the pressure inside the cartridge builds up to a predetermined point.

At the base of the cartridge the insert 102 also causes wave deformation and, in a manner similar to what has been described, this gives rise to a high pressure region more or less at the junction of the side wall with the base 32. A further factor comes into play in that the junction of the wall 34 with the base 32 is discontinuous and this further promotes the

generation of localised high pressures which subsequently cause fracturing of the rock in the region of the interface between the bottom 20 and the side wall 22 the hole.

When the cartridge fractures each insert 100 and 102 disintegrates, thereby producing a high pressure jet of material which is directed into the adjacent rock surface. This high pressure jet is of a material with a density which is significantly greater than the density of the propellant 42 or, for that matter, than the density of the material from which the cartridge is made. This latter material is usually a plastics material. Each insert thus gives rise to a high pressure jet of massive material which has considerable rock breaking capability.

It follows that by correctly positioning and shaping the inserts it is possible to initiate cracking of the rock at a chosen position.

The cartridge 30M shown in Figure 13 bears substantial similarities to what is shown in Figure 12 and where applicable like components are designated by means of like reference numerals. Again use is made of two inserts designated 100A and 100B respectively which are made from a suitable high density material. Each insert has a small explosive charge 104A and 104B respectively which is packed in close contact with the insert.

When the propellant 42 is ignited the explosive charges are detonated as the pressure wave advances through the propellant. In each case the explosive charge helps to disintegrate the heavy metal insert thereby producing a localised high pressure jet of material which is effective at initiating fracture of the adjacent rock. It is to be borne in mind that the effect of the explosive is enhanced by the ability of the insert and the explosive, prior to detonation, to deform the pressure wave which is generated by the combusting propellant.

It is possible to ignite the explosive charges by sending an appropriate control signal directly to the charges. Optionally, if necessary, use could be made of a local detonator at the explosive charges. The control signal can be transmitted via a control wire 46A which is directly electrically connected to the control wires 46. Alternatively separate control signals can be sent on the control wires 46 and 46A in order to detonate the explosive charges at a predetermined time relatively to the time at which the propellant 42 is ignited.

In Figure 14 a cartridge 30Q contains a ring of explosive material, designated 106, which is positioned on an inner surface of the wall 34. A control lead 46D extends from the explosive ring to a control unit 108.

Figure 15 illustrates somewhat schematically the use of the control unit 108 in conjunction with a circuit 110 which is associated with the initiator 44 and a circuit 112 which is associated with the explosive 106.

The control unit 108 is powered by an external source 114, for example a battery, and includes a wave generator 116 which produces coded pulses each of an appropriate shape and with a desired energy content, using techniques which are known in the art and which are impressed on the line 46.

The circuit 110 is preferably mounted inside a housing of the initiator 44 as is somewhat schematically illustrated in Figure 14. Similarly the circuit 112 is physically located adjacent the explosive ring 106, again as is indicated in Figure 14.

The circuit 110 includes a timer 118 and a capacitor 120. The mechanism 112 includes a separate timer 122 and a capacitor 124. An active component of the initiator 44 which, when energised, produces a hot spot which results in initiation of the propellant 42, is designated 126 in Figure 15. A similar hot spot initiator, which is used to detonate the explosive 106, is designated 128 and is connected to the timer 122. Hot spot initiators of this type are known in the art and consequently are not further described herein.

When the rock breaking process is commenced a control signal is sent from the unit 116 on the line 46 to the initiator 44. The control signal is also applied by the line 46C to the capacitor 124. The capacitors 120 and 124 are charged by the control signal to respective voltages which permit operation of the timers 118 and 122. These devices may communicate with each other via the line 46C and their operation can therefore be coordinated or synchronised so that each timer commences, at the same instant, timing a respective predetermined time interval. Through the use of suitable electronic circuitry highly accurate and precisely controlled timing intervals can be achieved.

When the timer 118 reaches the end of its timing interval energy from the charged capacitor 120 is discharged, by closing an internal switch in the timer, into the hot spot initiator 126. Similarly, at the end of the timing interval of the timer 122, closure of an internal switch in the timer causes the discharge of energy from the capacitor 124 into the hot spot initiator 128. When the hot spot initiator 126 is energised it causes combustion of the propellant 42. Similarly energisation of the hot spot initiator 128 causes detonation of the explosive 106. Normally the difference between the time at which the propellant is initiated and the time at which the explosive is detonated is small, of the order of micro-seconds, and although the combustion of the propellant takes place rapidly the resulting pressure wave does not cause the cartridge to disintegrate before the timer 122 causes the explosive 106 to be detonated. In other words although the propellant and the explosive are initiated in rapid succession the time interval between these two events can be precisely controlled in order to optimise the effect which the explosive has on the pressure wave which is released by the combustion of the propellant.

The control wires 46 and 46C may be conductive, for conveying electrical signals, or may be formed by fibre optic cables for conducting optical signals. In the latter case it is not feasible however to transmit meaningful quantities of energy from the control unit to the circuits 110 and 112. In this instance the capacitors 120 and 124 are dispensed with and are replaced by small onboard batteries which provide the required energy for operating the timers and for energising the respective hot spot initiators.

Figure 16 illustrates a wireless technique which is used in place of a physical connection between the control unit 108 and the cartridge. The control unit 108 includes a timer 130 which is powered from an electrical source 132. A transmitting antenna 134 is used to radiate a signal 136 to a receiving antenna 138 which is positioned at the initiator 44. The received signal is rectified by a diode 140 and the rectified output is used to charge a capacitor 142. An onboard timer 144 is powered by the capacitor 142 and, at an appropriate time which is measured by the timer, energy from the capacitor 142 is discharged into a hot spot initiator 146.

Clearly suitable safeguards must be built into the control system, which is used for firing the propellant, to ensure that stray signals from extraneous sources, including noise, do not inadvertently cause initiation of the propellant.

In Figure 17 a first initiator 44E is engaged with the cartridge 30R. The initiator is located at a rounded upper end of the cartridge. A second initiator 44F, which may be identical to the initiator 44E, is engaged with the base 32 of the cartridge.

Control wires 46C and 46D extend from the two initiators to a control unit, not shown, which is of conventional construction.

The control wires 46C and 46D may be electrically connected to each other or alternatively may extend separately to the control unit. In the former case one control signal may be impressed on the wires to energise the initiators 44E and 44F substantially simultaneously. In the second instance however separate control signals are impressed on the wires 46C and 46D respectively to energise the initiators 44E and 44F. With this form of the invention it is possible to fire the initiators at intervals which are slightly spaced, by a predetermined time interval, from each other.

When the initiators are fired the propellant material 42 in the region of each initiator is ignited and a rapid combustion process takes place which gives rise to the generation of two high pressure waves which advance towards each other from respective ends of the cartridge ie. from the initiators 44E and 44F. The pressure waves are accompanied by the release of high pressure jet materials which are substantially in gaseous form. The pressure waves

advance towards each other and depending on physical conditions inside the cartridge and the times at which the initiators are fired interfere or meet with each other approximately at a central region, designated 150, of the cartridge. Interference of the pressure waves gives rise to a high pressure, or high stress region, more or less at the middle of the cartridge.

Initially the cartridge contains the expanding high pressure jet material and deforms outwardly, without rupturing, so that the wall 34 of the cartridge is forced into intimate sealing contact with an opposing surface of the wall 22 of the hole. The cartridge does not fracture during this process for, as noted, it is preferably fabricated from a plastically deformable material.

The cartridge thus effectively confines the high pressure gas and the wall of the cartridge, since it is in close contact with the wall of the hole, effectively reinforces the wall.

The central region of the cartridge is, as noted, the region at which high stress concentrations occurs due to the interference of the two pressure waves with each other. Consequently when the cartridge ruptures the rock in the vicinity of the region 150 is initially fractured by the high pressure jet material.

It follows that by confining the high pressure jet material inside the cartridge and by allowing the two pressure waves to interfere with each other the cartridge can be caused to fracture at a desired point which means that the force which is released by the combusting propellant can then be directed onto a chosen surface of the wall of the hole adjacent the point or region at which the shock waves interfere.

Figure 17 also illustrates a variation of the invention. A dotted line 152 indicates that the volume which is occupied by the cartridge 30E could be occupied by two relatively smaller cartridges designated 30R1 and 30R2 respectively. Each cartridge carries a respective initiator 44E or 44F, substantially as shown in the drawing.

The cartridges are however orientated so that their respective bases, designated by the dotted line 152, abut each other with the cartridge assembly, which is elongate, being such that the initiators 44E and 44F are at opposed respectively points of the elongate assembly. The initiators are fired substantially simultaneously and pressure waves in each respective cartridge are then propagated towards the respective bases at which point the pressure waves interfere with each other, substantially in the manner which has been described and give rise, again, to a high stress region. In this case however the bases of the cartridges act to deflect the pressure waves outwardly and, through suitable design, this feature can be used to enhance the high stress region yet further. For example it is possible to form each base with a conical shape, as is indicated by means of dotted lines 154A and 154B

respectively, so that the pressure waves are initially deflected radially outwardly before interacting directly with each other.

Figure 18 illustrates a cartridge 30T which is similar in many respects to what has been shown in Figure 17 and where applicable like reference numerals are used to designate like components.

The initiators which are used in the arrangement of Figure 18 are, in this instance, made from an inert material such as carbon wire and are designated respectively 44G and 44H and are positioned adjacent a surface of the wall 34 of the cartridge. The initiators are directly exposed to the propellant 42 and are fixed under factory conditions to the cartridge 30T. The control wires 46C and 46D which lead to the initiators are embedded in the wall of the cartridge.

In the arrangement shown in Figure 19 each initiator is constituted by a substantially circular loop of filament wire 44X and 44Y respectively. As is the case with the Figure 18 embodiment each filament wire is made from an inert material such as carbon wire. "Inert" in this sense means a material which, in the absence of an electric current passing through the material, is not capable of emitting a spark or showing any other phenomenon which can cause ignition of a propellant. With the arrangement of Figure 19 the blasting agent is initiated, at each of two spaced locations, over a relatively substantial distance or area, or at a plurality of points. In the arrangement shown in Figure 18 on the other hand initiation takes place at relatively small regions which are spaced from each other. Different types of pressure waves are produced depending on the manner of initiation. Nonetheless the principle remains the same which is that the pressure waves are allowed to interfere with each other at a location which is between the points at which they originate in order to cause a localised high energy region which causes rock fracture in the vicinity of the region.